Clean Version of the Entire Set of Pending Claims

1. A DC to DC switching circuit for controlling power switching devices in a DC to DC converter having first and second interleaved converter circuits operating into a common load comprising:

a current sense circuit sensing the voltage across a sense resistor in series with the power supply supplying power to the power switching devices;

a first pulse width modulator controlling the power switching devices of the first converter circuit;

a second pulse width modulator controlling the power switching devices of the second converter circuit;

a feedback circuit responsive to the voltage across the common load;

control circuits for controlling the first and second pulse width modulators responsive to the feedback circuit and a commanded output voltage;

the control circuits also being responsive to the difference in the voltage across the sense resistor when the first converter is drawing power from the power supply through the sense resistor and the second converter is not, and when the second converter is drawing power from the power supply through the sense resistor and the first converter is not, to adjust the relative duty cycle

of the first and second converters to tend to minimize the difference in the voltage across the sense resistor;

the current sense circuit, the first pulse width modulator, the second pulse width modulator, the feedback circuit and the control circuits being in a single integrated circuit.

2. The DC to DC switching circuit of claim 1 wherein the sense resistor is external to the integrated circuit.

3. (Amended) The DC to DC switching circuit of claim 1 further comprised of an integrator having an output responsive to the integral of an error signal, the error signal being responsive to the voltage across the common load and a desired voltage, the control circuits also being responsive to the output of the integrator.

4. The DC to DC switching circuit of claim 3 wherein the time constant of the integrator is adjustable by the selection of at least one component external to the integrated circuit.

5. The DC to DC switching circuit of claim 3 further comprised of a differentiator having an output responsive to the rate of change of the voltage across the common load, the control circuits also being responsive to the output of differentiator.

6. The DC to DC switching circuit of claim 5 wherein the time constant of the differentiator is adjustable by the selection of at least one component external to the integrated circuit.

7. The DC to DC switching circuit of claim 1 wherein the control circuits are also responsive to rapid decreases in the voltage on the common load to turn on the first and second converter circuits independent of the phase of the first and second pulse width modulators.

8. The DC to DC switching circuit of claim 7 wherein the control circuits are also responsive to rapid increases in the voltage on the common load to turn off the first and second converter circuits independent of the phase of the first and second pulse width modulators.

9. The DC to DC switching circuit of claim 1 further comprised of a load variation circuit coupled to the control circuits to decrease the voltage on the common load for higher voltages across the current sense resistor and to increase the voltage on the common load for lower voltages across the current sense resistor.

10. (Amended) DC to DC switching circuit for controlling power switching devices in a DC to DC converter having first and second converter circuits operating into a common load comprising:

a first pulse width modulator controlling the power switching devices of the first converter circuit;

a second pulse width modulator controlling the power switching devices of the second converter circuit;

a feedback circuit responsive to the voltage across the common load;

control circuits for controlling the first and second pulse width modulators responsive to the feedback circuit, the operation of the first and second pulse width modulators being interleaved;

the control circuits also being responsive to the difference in current through the first converter and the second converter to adjust the relative duty cycle of the first and second converters to tend to minimize the difference in the voltage across a sense resistor;

the first pulse width modulator, the second pulse width modulator, the feedback circuit and the control circuits being in a single integrated circuit.

11. The DC to DC switching circuit of claim 10 wherein the commanded output voltage is controllable through an input to the integrated circuit.

12. The DC to DC switching circuit of claim 10 wherein the commanded output voltage is controllable through a digital input to the integrated circuit.

13. (Amended) The DC to DC switching circuit of claim 12 further comprised of an integrator having an output responsive to the integral of an error signal, the error signal being responsive to the voltage across the common load and a desired voltage, the control circuits also being responsive to the output of the integrator.

14. The DC to DC switching circuit of claim 13 wherein the time constant of the integrator is adjustable by the selection of at least one component external to the integrated circuit.

15. The DC to DC switching circuit of claim 13 further comprised of a differentiator having an output responsive to the rate of change of the voltage across the common load, the control circuits also being responsive to the output of differentiator.

16. The DC to DC switching circuit of claim 15 wherein the time constant of the differentiator is adjustable by the selection of at least one component external to the integrated circuit.

17. The DC to DC switching circuit of claim 12 wherein the control circuits are also responsive to rapid decreases in the voltage on the common load to turn on the first and second converter circuits independent of the phase of the first and second pulse width modulators.

18. The DC to DC switching circuit of claim 17 wherein the control circuits are also responsive to rapid increases in the voltage on the common load to turn off the first and second converter circuits independent of the phase of the first and second pulse width modulators.

19. The DC to DC switching circuit of claim 12 further comprised of a load variation circuit coupled to the control circuits to decrease the voltage on the common load for higher currents through the converters and to increase the voltage on the common load for lower currents through the converters.

20. The DC to DC switching circuit of claim 12 wherein the commanded output voltage is controllable through an input to the integrated circuit.

21. The DC to DC switching circuit of claim 12 wherein the commanded output voltage is controllable through a digital input to the integrated circuit.

22. (Twice Amended) A DC to DC converter having a plurality of converter circuits for operating into a common load, comprising:

a plurality of buck converter circuits operating into the common load, each buck converter circuit having an inductor for alternately conducting between first and second power supply terminals, and the second power supply terminal and the common load;

a plurality of pulse width modulators driven by a common oscillator in an interleaved manner, each pulse width modulator controlling one of the plurality of buck converter circuits, whereby the operation of the buck converter circuits is interleaved;

a feedback circuit responsive to a voltage across the common output;

a voltage control circuit controlling the plurality of pulse width modulators responsive to the feedback circuit and a commanded output voltage; and

a current balance control circuit responsive to the difference in current in the plurality of interleaved buck converter circuits and controlling the pulse width modulators to balance the current in the plurality of interleaved buck converter circuits;

the plurality of pulse width modulators and the control circuits being in a single integrated circuit.

24. (Twice Amended) The DC to DC converter of claim 22 further comprised of an integrator having an output responsive to the integral of an error signal, the error signal being responsive to the voltage across the common load and a desired voltage, the control circuits also being responsive to the output of the integrator.

25. (Amended) The DC to DC converter of claim 24 wherein a time constant of the integrator is adjustable by the selection of at least one component external to the integrated circuit.

26. (Amended) The DC to DC converter of claim 24 further comprised of a differentiator having an output responsive to the

rate of change of the voltage across the common load, the control circuits also being responsive to the output of differentiator.

27. (Amended) The DC to DC converter of claim 26 wherein the time constant of the differentiator is adjustable by the selection of at least one component external to the integrated circuit.

28. (Amended) The DC to DC converter of claim 22 wherein the control circuits are also responsive to rapid decreases in the voltage across the common load to turn on the plurality of buck converter circuits independent of the phase of the plurality of pulse width modulators.

29. (Amended) The DC to DC converter of claim 28 wherein the control circuits are also responsive to rapid increases in the voltage across the common load to turn off the plurality of buck converter circuits independent of the phase of the plurality of pulse width modulators.

30. (Amended) The DC to DC converter of claim 22, wherein the plurality of pulse width modulators consist of a pair of pulse width modulators.

31. (Amended) The DC to DC converter of claim 22 wherein the feedback circuit is in the single integrated circuit.

32. (Twice Amended) A DC to DC converter having a plurality of converter circuits operating into a common load, comprising:

a plurality of buck converter circuits operating into the common load, each buck converter circuit having an inductor for alternately conducting between first and second power supply terminals, and the second power supply terminal and the common load;

a plurality of pulse width modulators each controlling one of the plurality of buck converter circuits, the operation of the pulse width modulators and the buck converter circuits being interleaved;

a feedback circuit responsive to a voltage across the common load;

control circuits responsive to the feedback circuit and a commanded output voltage to control a nominal duty cycle of the plurality of buck converter circuits, the control circuits also being responsive to the difference in current in the plurality of interleaved buck converter circuits to adjust a relative duty cycle of the plurality of buck converter circuits to balance the current in the buck converter circuits;

the plurality of pulse width modulators and the control circuits being in a single integrated circuit.

34. (Twice Amended) The DC to DC converter of claim 32 wherein the control circuits control the plurality of pulse width modulators.

35. (Amended) The DC to DC converter of claim 32 further comprising an integrator having an output responsive to the integral of an error signal, the error signal being responsive to the voltage across the common load and a desired voltage.

36. (Twice Amended) The DC to DC converter of claim 35, wherein the control circuits are also responsive to the output of the integrator.

37. (Amended) The DC to DC converter of claim 35 wherein a time constant of the integrator is adjustable by the selection of at least one component external to the integrated circuit.

38. (Amended) The DC to DC converter of claim 35 further comprising a differentiator having an output responsive to a rate of change of the voltage across the common load, the control circuits also being responsive to the output of differentiator.

39. (Amended) The DC to DC converter of claim 38 wherein a time constant of the differentiator is adjustable by the

selection of at least one component external to the integrated circuit.

40. (Amended) The DC to DC converter of claim 32 wherein the control circuits are also responsive to rapid decreases in the voltage across the common load to turn on the plurality of buck converter circuits, independent of the phase of the plurality of pulse width modulators.

41. (Amended) The DC to DC converter of claim 32 wherein the control circuits are also responsive to rapid increases in the voltage across the common load to turn off the plurality of buck converter circuits, independent of the phase of the plurality of pulse width modulators.

42. (Amended) The DC to DC converter of claim 32, wherein the plurality of pulse width modulators consist of a pair of pulse width modulators.

43. (Amended) The DC to DC converter of claim 32 wherein the commanded output voltage is controllable through an input to the integrated circuit.

44. (Amended) The DC to DC converter of claim 32 wherein the feedback circuit is in the single integrated circuit.

45. (Twice Amended) A DC to DC converter having a plurality of converter circuits operating into a common load, comprising:

a plurality of buck converter circuits operating into the common load, each buck converter circuit having an inductor for alternately conducting between first and second power supply terminals, and the second power supply terminal and the common load;

a plurality of pulse width modulators each controlling one of the plurality of buck converter circuits, the operation of the pulse width modulators being interleaved;

control circuits for adjusting a nominal duty cycle of the plurality of interleaved buck converter circuits, the control circuits also being responsive to the difference in current in the plurality of interleaved buck converter circuits to adjust the relative duty cycle of the plurality of buck converter circuits to balance the current therein;

the plurality of pulse width modulators and the control circuits being in a single integrated circuit.

46. (Amended) A DC to DC converter having first and second converter circuits operating into a common load, comprising:

first and second buck converter circuits operating into the common load, each buck converter circuit having an inductor for

alternately conducting between first and second power supply terminals, and the second power supply terminal and the common load;

a first pulse width modulator controlling the first buck converter circuit;

a second pulse width modulator controlling the second buck converter circuit;

a feedback circuit responsive to the voltage across the common load;

control circuits for controlling the first and second pulse width modulators responsive to the feedback circuit;

the control circuits also being responsive to current measurements in the first buck converter circuit and the second buck converter circuit for adjusting the relative duty cycle of the first and second pulse width modulators to balance the currents in the buck converter circuits;

the first pulse width modulator, the second pulse width modulator, the feedback circuit and the control circuits being in a single integrated circuit.

47. (Amended) A DC to DC converter having a plurality of converter circuits operating into a common load, comprising:

a plurality of buck converter circuits operating into the common load, each buck converter circuit having an inductor for alternately conducting between first and second power supply

terminals, and the second power supply terminal and the common load;

a plurality of pulse width modulators driven by a common oscillator in an interleaved manner, each pulse width modulator controlling one of the plurality of buck converter circuits, whereby the operation of the buck converter circuits is interleaved;

a feedback circuit responsive to a voltage across the common load;

a voltage control circuit for controlling the plurality of pulse width modulators responsive to the feedback circuit and a commanded output voltage; and

a current balance control circuit responsive to the difference in current in the plurality of interleaved buck converter circuits for controlling the pulse width modulators to balance the current in the plurality of interleaved buck converter circuits.

48. (Amended) A DC to DC converter having a plurality of converter circuits operating into a common load, comprising:

a plurality of buck converter circuits operating into the common load, each buck converter circuit having an inductor for alternately conducting between first and second power supply terminals, and the second power supply terminal and the common load;

a plurality of pulse width modulators each controlling power switching devices of one of the plurality of interleaved buck converter circuits, the operation of the pulse width modulators and the buck converter circuits being interleaved;

a feedback circuit responsive to a voltage across the common load;

control circuits responsive to the feedback circuit and a commanded output voltage to control a nominal duty cycle of the plurality of buck converter circuits, the control circuits also being responsive to the difference in current in the plurality of interleaved buck converter circuits to adjust the relative duty cycle of the plurality of buck converter circuits to balance the current in the buck converter circuits.

49. (Amended) A DC to DC converter having a plurality of converter circuits operating into a common load, comprising:

a plurality of buck converter circuits operating into the common load, each buck converter circuit having an inductor for alternately conducting between first and second power supply terminals, and the second power supply terminal and the common load;

a plurality of pulse width modulators each controlling one of the plurality of buck converter circuits, the pulse width modulators being driven by a common oscillator signal so that the operation of the pulse width modulators is interleaved;

control circuits for adjusting a nominal duty cycle of the plurality of interleaved buck converter circuits to control a voltage on the common load, and for responding to the difference in current in the plurality of interleaved buck converter circuits to adjust the relative duty cycle of the plurality of buck converter circuits to balance the current in the buck converter circuits.

50. (Amended) A DC to DC converter having first and second converter circuits operating into a common load, comprising:

first and second buck converter circuits operating into the common load, each buck converter circuit having an inductor for alternately conducting between first and second power supply terminals, and the second power supply terminal and the common load;

a first pulse width modulator controlling the first buck converter circuit;

a second pulse width modulator controlling the second buck converter circuit;

a feedback circuit responsive to the voltage across the common load;

control circuits for controlling the first and second pulse width modulators responsive to the feedback circuit;

the control circuits also being responsive to current measurements through the first buck converter circuit and the

second buck converter circuit to adjust the relative duty cycle of the first and second buck converter circuits.

51. (Amended) A DC to DC converter comprising:

a plurality of buck converter circuits operating into the common load, each buck converter circuit having an inductor for alternately conducting between first and second power supply terminals, and the second power supply terminal and the common load;

a plurality of pulse width modulators driven by a common oscillator in an interleaved manner, each pulse width modulator controlling one of the plurality of buck converter circuits, whereby the operation of the buck converter circuits is interleaved;

a feedback circuit responsive to a voltage on the common output;

a voltage control circuit for controlling the plurality of pulse width modulators responsive to the feedback circuit and a commanded output voltage; and

a current balance control circuit for controlling the pulse width modulators responsive to a difference in current in the inductors of the plurality of interleaved buck converter circuits to balance the current in the plurality of interleaved buck converter circuits;

the plurality of pulse width modulators and the control circuits being in a single integrated circuit.

52. (Amended) A DC to DC converter having a plurality of converter circuits operating into a common load, comprising:

a plurality of buck converter circuits operating into the common load, each buck converter circuit having an inductor for alternately conducting between first and second power supply terminals, and the second power supply terminal and the common load;

a plurality of pulse width modulators each controlling power switching devices of one of the plurality of buck converter circuits, the operation of the pulse width modulators and the buck converter circuits being interleaved;

a feedback circuit responsive to a voltage across the common load;

control circuits being responsive to the feedback circuit and a commanded output voltage to control a nominal duty cycle of the plurality of buck converter circuits, the control circuits also being responsive to the difference in currents in the plurality of interleaved buck converter circuits to adjust the relative duty cycle of the plurality of buck converter circuits to balance the current in the buck converter circuits;

the plurality of pulse width modulators and the control circuits being in a single integrated circuit.

53. (Amended) A DC to DC converter having first and second converter circuits operating into a common load, comprising:

first and second buck converter circuits operating into the common load, each buck converter circuit having an inductor for alternately conducting between first and second power supply terminals, and the second power supply terminal and the common load;

a first pulse width modulator controlling the first buck converter circuit;

a second pulse width modulator controlling the second buck converter circuit;

a feedback circuit responsive to the voltage across the common load;

control circuits for controlling the first and second pulse width modulators responsive to the feedback circuit;

the control circuits also being responsive to current measurements in the first buck converter circuit and the second buck converter circuit to adjust the relative duty cycle of the first and second buck converter circuits;

the first pulse width modulator, the second pulse width modulator, the feedback circuit and the control circuits being in a single integrated circuit.

54. (Amended) A DC to DC converter having a plurality of converter circuits operating into a common load, comprising:

a plurality of buck converter circuits operating into the common load, each buck converter circuit having an inductor for alternately conducting between first and second power supply terminals, and the second power supply terminal and the common load;

a plurality of pulse width modulators driven by a common oscillator in an interleaved manner, each pulse width modulator controlling one of the plurality of buck converter circuits, whereby the operation of the buck converter circuits is interleaved;

a feedback circuit responsive to a voltage across the common load;

a voltage control circuit for controlling the plurality of pulse width modulators responsive to the feedback circuit and a commanded output voltage; and

a current balance control circuit for controlling the pulse width modulators to balance the current in the plurality of interleaved buck converter circuits responsive to the difference in current in the plurality of interleaved buck converter circuits.

55. (Amended) A DC to DC converter having a plurality of converter circuits operating into a common load, comprising:

a plurality of buck converter circuits operating into the common load, each buck converter circuit having an inductor for alternately conducting between first and second power supply terminals, and the second power supply terminal and the common load;

a plurality of pulse width modulators each controlling power switching devices of one of the plurality of interleaved buck converter circuits, the operation of the pulse width modulators and the buck converter circuits being interleaved;

a feedback circuit responsive to a voltage across the common load;

control circuits responsive to the feedback circuit and a commanded output voltage to control a nominal duty cycle of the plurality of buck converter circuits, the control circuits also adjusting a relative duty cycle of the plurality of buck converter circuits to balance the current in the buck converter circuits responsive to the difference in current in the plurality of interleaved buck converter circuits.

56. (Amended) A DC to DC converter having a plurality of converter circuits operating into a common load, comprising:

a plurality of buck converter circuits operating into the common load, each buck converter circuit having an inductor for alternately conducting between first and second power supply terminals, and the second power supply terminal and the common load;

a plurality of pulse width modulators each controlling one of the plurality of buck converter circuits, the pulse width modulators being driven by a common oscillator signal so that the operation of the pulse width modulators is interleaved;

control circuits for adjusting a nominal duty cycle of the plurality of interleaved buck converter circuits to control a voltage on the common load, and for adjusting a relative duty cycle of the plurality of buck converter circuits to balance the current in the buck converter circuits.

57. (Amended) A DC to DC converter having first and second buck converter circuits operating into a common load, comprising:

first and second buck converter circuits operating into the common load, each buck converter circuit having an inductor for alternately conducting between first and second power supply terminals, and the second power supply terminal and the common load;

a first pulse width modulator controlling the first buck converter circuit;

a second pulse width modulator controlling the second buck converter circuit;

a feedback circuit responsive to the voltage across the common load;

control circuits for controlling the first and second pulse width modulators responsive to the feedback circuit;

the control circuits also being responsive to current measurements in the first buck converter circuit and the second buck converter circuit to adjust the relative duty cycle of the first and second buck converter circuits.

58. (New) A DC to DC converter having a plurality of converter circuits for operating into a common load, comprising:

a plurality of buck converter circuits operating into the common load, each buck converter circuit having an inductor for alternately conducting between first and second power supply terminals, and the second power supply terminal and the common load;

a plurality of pulse width modulators driven by a common oscillator in an interleaved manner, each pulse width modulator controlling one of the plurality of buck converter circuits, whereby the operation of the buck converter circuits is interleaved;

a feedback circuit responsive to a voltage across the common output;

a voltage control circuit controlling the plurality of pulse width modulators responsive to the feedback circuit and a commanded output voltage;

the plurality of pulse width modulators and the control circuits being in a single integrated circuit.

59. (New) The DC to DC converter of claim 58 further comprising the common oscillator, the common oscillator also being in the single integrated circuit.

60. (New) A DC to DC converter having a plurality of converter circuits operating into a common load, comprising:

a plurality of buck converter circuits operating into the common load, each buck converter circuit having an inductor for alternately conducting between first and second power supply terminals, and the second power supply terminal and the common load;

a plurality of pulse width modulators each controlling one of the plurality of buck converter circuits, the operation of the pulse width modulators and the buck converter circuits being interleaved;

a feedback circuit responsive to a voltage across the common load;

control circuits responsive to the feedback circuit and a commanded output voltage to control a nominal duty cycle of the plurality of buck converter circuits;

the plurality of pulse width modulators and the control circuits being in a single integrated circuit.

61. (New) The DC to DC converter of claim 60 further comprising the common oscillator, the common oscillator also being in the single integrated circuit.

62. (New) A DC to DC converter comprising:

first and second buck converter circuits operating into a common load, each buck converter circuit having an inductor for alternately conducting between first and second power supply terminals, and the second power supply terminal and the common load;

first and second pulse width modulators driven by a common oscillator in an interleaved manner, each pulse width modulator controlling a respective one of the first and second buck converter circuits, whereby the operation of the buck converter circuits is interleaved;

a feedback circuit responsive to a voltage across the common output;

the plurality of pulse width modulators and the control circuits being in a single integrated circuit.

65. (New) The DC to DC converter of claim 64 further comprising the common oscillator, the common oscillator also being in the single integrated circuit.

a voltage control circuit controlling the first and second pulse width modulators responsive to the feedback circuit and a commanded output voltage;

the plurality of pulse width modulators and the control circuits being in a single integrated circuit.

63. (New) The DC to DC converter of claim 62 further comprising the common oscillator, the common oscillator also being in the single integrated circuit.

64. (New) A DC to DC converter comprising:

first and second buck converter circuits operating into a common load, each buck converter circuit having an inductor for alternately conducting between first and second power supply terminals, and the second power supply terminal and the common load;

first and second pulse width modulators each controlling a respective one of the buck converter circuits, the operation of the pulse width modulators and the buck converter circuits being interleaved;

a feedback circuit responsive to a voltage across the common load;

control circuits responsive to the feedback circuit and a commanded output voltage to control a nominal duty cycle of the plurality of buck converter circuits;